I. C. 7016 May 1938

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

SMOKE ABATEMENT

SELECTIONS FROM PAPERS BY O. P. HOOD

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J. F. BARKLEY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SMOKE ABATEMENT[1]

Selections from papers by O. P. Hood
Compiled by J. F. Barkley[2]

FOREWORD

This information circular on "Smoke Abatement" comprises selections from papers by the late O. P. Hood, formerly chief engineer, Mechanical Division and chief, Technologic Branch, Bureau of Mines. There are many basic or fundamental ideas connected with the problem of city smoke abatement that no doubt will be as important in the years to come as they have been in the past. It is a matter in which any citizen of a community may become interested and due to its apparent simplicity feel that he has an adequate grasp of the subject; yet many basic conceptions may have escaped him entirely. These basic ideas have been expressed so clearly by Mr. Hood, with his peculiar abilities and training, that it was considered desirable to assemble certain of his writings on this subject in one publication available to the general public, and for use in answering many general inquiries about smoke abatement that come to this Bureau. The paper delivered before the citizens' smoke abatement conference at St. Louis has not been abridged but is given complete as it forms a well-rounded discussion of the subject.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Inf. Cir. 7016."

2/ Supervising engineer, Fuel Economy Service, Bureau of Mines, Washington, D. C.

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KEEPING THE ATMOSPHERE CLEAN[3/]

By O. P. Hood

WHY IS IT that smoke-abatement efforts do not bring more satisfactory results?

The main reason is an incorrect estimate of the kind and size of the job. When an industrial community realizes that keeping the air clean is a project of similar magnitude to keeping streets clean, providing clean water, removing city waste, or guarding the moral atmosphere, then there may be a real hope of success. We usually think of the project in too small terms. It is thought of as is the dog catcher or the boiler inspector--a matter of a man or two, a job or two, a small appropriation of variable and uncertain amount, to be abolished in a fit of economy and reestablished under pressure of a vigorous minority. Even so, it is surprising how much is obtained for the effort; but the community is rarely satisfied, for the job is bigger than it was conceived to be. Continuous, never-ceasing effort is required to clean up a smoky city. A few months of relaxation and the situation slips back some years of effort.

It is useless to look for a spectacular cure. Success comes only after long continued highly skillful effort. When a new plant goes in and it proves to be a smoker, it is difficult to remedy the condition. The community will probably have to stand smoke for a long time while the owner spends money temporizing with weak expedients, finally arriving at the conclusion that "it cannot be done." The remedy is to provide such engineering oversight of new installations as to insure a non-smoking plant to begin with. This can be done. It may mean changes in building plans, a larger investment, a greater responsibility of management, a more intelligent operation, but these things are the price of clean air. The higher grade of installation usually pays well by reducing running expenses. It is of little use to complain of smoky stacks and allow new ones to be added daily. It is not often that smokelessness is one of the main objectives in an installation. Capacity, convenience, efficiency, and low cost come first, with a weak but laudable hope that smokelessness can be had also at no increase in cost. The order must be reversed in the public mind if we are to have clean air. Smokelessness must be a first requirement. These simple illustrations indicate that successful smoke abatement is a problem requiring high technical ability, the administration of a difficult human problem, a change in attitude of a community, a willingness to wait for results, and a readiness to pay for continuous, long-time effort free from political control. So far we have not found this combination, so that results are partial.

There is a great waste of ineffective effort in smoke-abatement agitation that gets nowhere, because of a lack of vision as to the kind of job it is and an unwillingness to pay the price. Engineers believe that it can be done, and at a price not out of proportion to its worth.

3/ Mech. Eng., vol. 48, 1926, p. 388.

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METHODS OF SMOKE ABATEMENT[4/]

By O. P. Hood

It is necessary to begin with definitions. A generation ago "smoke" was the visible output from a stack discharging products of combustion. It was usually described as some shade of black, light or dark, or dense, or only a haze. Complaints were largely against "dense black smoke" and "smoke abatement" meant the elimination of such smoke except for short periods of time, when smoking was considered to be inevitable.

At the present time the term "smoke" has a much more comprehensive meaning. It is being used to cover all undesirable material coming from a stack delivering products of combustion into the atmosphere. In addition to the visible smoke of all shades, it includes the almost invisible ash and totally invisible harmful gas. In any discussion of the subject of "smoke abatement" it must be made clear just what is meant by smoke.

The word "abate" or to beat down, means to "totally eliminate", but it also has the meaning "to lessen." This double meaning creates confusion of thought, so that an understanding must be reached as to what is meant by abatement.

No spot has ever been found at the surface of the earth where the air is dust free. The sky is said to be blue because of finely divided matter of some sort that affects the light passing through. The definition of "pure air" or the objective of "smoke abatement" requires that the threshold of quantities beyond which the air shall be considered impure shall be defined technically. The human mechanism is adapted to use somewhat impure respirable fluid without injury or annoyance. Shall the determination of the amount of allowable impurity be determined by some technically defined limit beyond which damage is done to the person or to property, or shall we rest content with the simple statement "we do not like it", and arbitrarily declare it to be a nuisance? The technical man demands a technical definition in order that industries may conform to the community desire. At the present time there are practically no definitions that are technically sound or acceptable. In the present state of the art the medical profession does not furnish a clear definition of what constitutes a harmful atmosphere except in regard to very few things. For instance, the limit of allowable carbon monoxide in the air is pretty definitely determined.

Before threshold limits can be defined the objectionable characteristics of quantities involved must be known. There is no unanimity of opinion on this matter and much remains to be learned. For instance, silica dust is blamed for the lung disease called silicosis. It was at first believed that the sharp edges of the dust particles mechanically irritated the tissue. Later it was the belief that solubility of the free silica was the undesirable factor and there are now proponents of a theory that something else than silica is the main factor. That dust of any kind seriously reduces the amount of ultraviolet light reaching

4/ Excerpts from unpublished memorandum.

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the human being is now held to be an offending characteristic. What then about silica dust should we measure? It is necessary to know what to measure and how to measure it regarding each deleterious material in air before definitions can be made.

This is the field of research and research requires long-time constant support. Temporary emergency effort over short periods can not help much, but it is in this field of research that the greatest good for smoke abatement can be accomplished since definitions are necessary before a rational treatment of the subject can be had.

It may be that it is sufficient for the present to fall back upon a less rational basis of definition. It may be enough to simply say "we don't like it" and recognize the intuitive feeling as nature's way of self-protection. For the lack of a better basis at present we are compelled to recognize such an arbitrary basis for definition, so that we define "smoke" as something accompanying combustion that the community does not like and define "abatement" as the reduction of the amounts involved to the point where the community will accept it. The ideals of "pure air" are continually changing; they vary in different communities and with the dominance of industry. Sometimes a community accepts what it must. Usually if there is no visible output from a stack the community raises no objection.

There are a few fuels such as anthracite, coke and gas, that can be easily burned with no visible smoke. Anthracite and coke may, however, deliver considerable ash in the air, and gas can be made to smoke. It is probably true that generally clean air can not be had until some form of relatively smokeless fuel shall be universally available. Experience with anthracite indicates that the characteristic of smokelessness is not sufficient to guarantee universal use. Each fuel has limitations peculiar to itself. Even at the same price anthracite would not be used where high rates of combustion are demanded in order to justify plants erected on expensive land, and where capital investment is a dominant factor. Even at the same price coke would not be used by many people because of its bulk and its peculiar burning characteristics. The one fuel more likely to become universal, if available, would be gas.

There is ample experience to show that the community will not pay an increased amount for fuel service for the single characteristic of smokelessness. Some individuals will pay but many individuals will not. If the use of a smokeless fuel is made compulsory for all it must be furnished at a cost for service no greater than that of a competing smoky fuel. This is the objective of all processed fuels, but so far has not been realized in any country.

Furthermore, any fuel can be burned smokelessly, so that it is unreasonable to give any one fuel a monopoly. The first requirement for complete combustion is that the equipment must be designed for the particular fuel used. Second, certain combustion conditions as to time, temperature and turbulence must be continuously maintained. Third, intelligent management and skilled operation must be constantly available. These three conditions are best met in large plants where coal burning is concentrated.

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New large plants now being designed take the smoke problem seriously and such plants are no longer main offenders. Not long ago such large plants gave the smoke problem scant consideration, so that the modernizing of old plants is good "smoke abatement."

The railroads present a peculiar problem and they are still producers of much smoke except where pressure is maintained on the operating organization. The small industries, apartment houses, and domestic fires are now the main producers of smoke.

The equipment used in these plants has not been designed for any one fuel but has always been a compromise with cost the dominating factor. The same devices are still installed for any fuel from gas to high volatile coal. To change this equipment would require assurance that a single type of fuel would always be available at minimum cost over a long period of time. To change all plants to new equipment would probably be prohibitive.

The third requirement for smokeless combustion is skilled operation and intelligent management. This is a matter of education and propaganda. It will not totally eliminate smoke nor entirely solve the problem, but it will greatly reduce smoke and a part of it may produce permanent betterment. Statistical inquiry can be made, to define present performance to which reference can later be made to measure the amount of improvement. This is a necessary part of smoke abatement and is also needed to allocate responsibility for smoke to guide technicians in methods of abatement and to justify expenditures by showing the amount of improvement. It is desirable to educate management in order that proper equipment and fuel shall be bought and that operation shall be effectively supervised and proper wages paid for skill. It is necessary to teach firing methods, to make known the facts of combustion, to further the use of effective devices, and oppose ineffective ones.

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PROGRESS AND POSSIBILITIES IN THE ABATEMENT OF SMOKE5/

By O. P. Hood

The last two decades have shown some notable efforts in smoke abatement in such cities as Chicago, St. Louis, Cleveland, Cincinnati, and Salt Lake City. In no case has complete success been attained in the sense of eliminating the problem and attaining clear skies. Based on the condition that would have been, however, had there been no special effort, considerable success can be claimed. It is generally conceded that an absence of smoke will be had only when smokeless fuels are universally used. This period has proved that, to be universally used, smokeless fuels must be no more expensive for the service performed than smoky fuels. At present such a condition exists in only a few localities. The dream of cheap processed fuels has not as yet become a reality, but it is a desirable ideal toward which there is much striving and which is realized in part.

A Major Problem

There is a growing appreciation of the fact that the maintenance of clean air in a city is a major problem comparable with the maintenance of clean water, clean streets and sewage, and garbage removal. So long as it is considered a minor matter in municipal housekeeping, only partial and indifferent successes are obtained. The past 20 years have shown that the best method of dealing with the problem is to have an engineering service that can lead by demonstration and good advice, telling people just what to do and seeing that it is done. This means leadership, rather than spotting and fining offenders. It means control of all new installations and a program of continued education of firemen and citizens who care for their own furnaces. The engineering problems of the large fuel-burning plants are less acute as to black smoke than formerly, but far more difficult in respect to dust and gases. The part that domestic smoke plays in the nuisance has been demonstrated, and this still remains the most difficult part of the problem. The general introduction of small stokers for domestic furnaces seems possible and promises a great help in reducing smoke from this source.

A politician of long experience once said that a question which depended on a moral issue could command only about one-third of the vote, while if it was made to appear to be a business matter, it could command a good majority. Smoke abatement work has attempted to justify itself by appeal to a number of different reasons, but no single argument has been sufficient to command a good, vigorous majority.

To abate smoke as a duty to the community appeals to less than a majority. The accompanying money saving of fuel appeals to a few. The appeal to health is perhaps the most potent, and it is for this reason

5/ The American City, September 1930, pp. 125-26.

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that this matter, though clearly an engineering affair, is so often placed in the department of public health for administration. In general, the attempt to show a direct relation between smoke and ill health has been disappointing to those demanding rigid demonstration. This has resulted not so much in throwing doubt on the reality of such connection as in strengthening the belief that the matter is so complicated that the methods of proof have not as yet been adequate to cope with the difficulties of the problem. The health argument has been greatly strengthened of late by the newer ideas of the part which short rays of sunlight play in our well-being, and of the part depression of spirit plays in good health.

Before we have scientific proof of these things, it may be that another argument may prove to be the most potent. There has never been a time when the material well-being of the mass of humanity has increased so rapidly as in the last generation. For many things it is no longer required to show necessity, or even good reason, to justify a purchase. Instead, we simply justify our luxuries because it is fitting that we have them. It is the habit of the time and it pleases us to drive an auto where we used to walk. It is fast becoming a sufficient argument against a smoky atmosphere that we "just don't like it." The argument "just because" has always been one hard to beat. Logic, facts, mathematical demonstration, an appeal to reason, have all retired in defeat before some little woman whose only argument is "just because."

Our Standards Have Risen

It may well be that the rising plane of individual and community living may soon reach an elevation where the general sensitiveness to discomfort will demand cleaner surroundings and not require a mathematical demonstration of our discomfort. The campaign against noise would indicate something of the kind. Are we more sensitive to noise, knowing its uselessness, than we used to be? And with means to buy comfort, are we less disposed to stand discomfort? The feelings that accompany a higher plane of living and that are not dependent upon logic or demonstration must not be overlooked. They may well be expressed by the old argument "just because."

It can hardly be said that we have attained a high degree of success in our smoke abatement efforts. Our successes are qualified. Before we have attained general success in abating black smoke, the standard of our desire has risen, so that now we object to the dust of white ash and pearl-grey coke, although recently sterilized in a white-hot furnace. Compared to the dust of our cities when horse manure littered our streets, the present dust from our chimneys is a refined product, but there is no doubt about its being a nuisance according to our newly acquired standards. Black smoke and dust and cinders we can see, and we are annoyed by them, but now our standard demands the elimination of even unseen gases that come from the sulphur of burning coal. While we cannot see these gases, we do see their effect in corrosion of metals, in deterioration of stone,

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discoloration of paint, and death of vegetation. And so we can expect the standard of our desire to continually outstrip our means of attaining it. This should not be a matter of discouragement, but should convince us that we had best get busy and support a real effort to gain control of the situation by rational engineering methods.

How Can We Get and Pay for the Needed Engineering Service?

There is an awkward period in smoke abatement matters when the small city outgrows its village habiliments and really needs the full dress of the larger city. The small city is almost proud of the smoke of its industries. When it gets to be too much of a good thing, an ordinance is passed making the emission of dense black smoke a finable offense. The administration of the law is found to be difficult, and it soon becomes evident that merely passing a punitive law is a poor way of dealing with the matter. Engineering ability is needed to guide smoky chimneys into the way of cleanliness. But the city can neither find nor pay for the adequate service needed. To administer a punitive law is cheap, while to install the cheapest effective engineering service is so much more expensive that the town must grow up before it can afford the really needed service. This is the awkward period, and I know of no satisfactory solution of the problem. At such a time there is not enough of the strictly engineering work of a high order to keep a good man busy or to justify giving him the living he deserves and can win in other fields of effort.

There ought to be some way whereby the needs and funds of several moderate-sized cities could be pooled in order to support a really able smoke abatement crew who could apply the newer methods of leadership to the problem. Their part-time service in each community might supplement the continued effort of local help to carry on. Most of the inquiries for help come from these in-between cities which find themselves dissatisfied with the results of the old, but too small to afford the mechanism of the new. Capable men are hard to find to fill this need, because the work has not paid enough to be attractive.

Since the problem is largely an educational one, is it possible that a solution might be found by calling on the university engineering department in each state to work out a service plan, the overhead to be paid by the state while the expense of operation is borne, according to the service rendered, by the several municipalities served?

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PRACTICAL SUGGESTIONS ON SMOKE ABATEMENT6/

Address Before the Citizens' Smoke Abatement Conference at St. Louis.

By O. P. HOOD

This subject of smoke abatement is at least ancient, if not very honorable. In 1301, Edward the First prohibited the use of coal in London because of "the unsavory vapors therefrom." Along in sixteen hundred and something there was a commission to look into the subject of smoke in London. In 1818, a royal commission was started in London, and since that time to the present the Englishman has been particularly exercised over this problem of smoke abatement, and the net result of all these commissions and talks so far is that London has the reputation of being one of the smokiest cities in the world.

I am afraid that introduction will be considered as something of a wet blanket, and yet there are good reasons why a problem of this kind should be attacked by people who know the actual facts before they begin. Perhaps I ought to tell you some of my credentials for talking on this subject tonight. I grew up in Indianapolis, where Brazil Block coal was the friend of my boyhood. I still remember the rich gobs of good fat soot that used to come out of our chimney. I lived for some years in your rival community - Pittsburgh - which has some reputation for smoke nuisance. Perhaps, however, the best word that I can say for myself is that for the last 15 years I have been connected with the Government movement for conservation of our mineral resources, and, of course, that includes coal, and at the beginning of the Bureau of Mines an interest was taken in the subject of abating smoke for, in the popular mind, it indicates waste of coal. While that is true, the waste is somewhat different from the popular conception. The actual amount of carbon that comes out of the stack is a woefully small percentage, but nevertheless whereever you find a lot of black smoke there is almost always inefficient operation and management, and it is therefore an evidence of waste.

Opportunity For Observation

I have had an opportunity therefore of observing the many smoke-abatement movements that have been started, have had a brief existence, have died a natural death, have been laid away until the same causes that started it in the first place recur and we have another smoke-abatement movement. It has come to the point where we think we can see the several steps in this cycle which recurs so frequently in American and European cities. In every industrial city we begin to see the symptoms and are able somewhat to predict the next step. It seems to progress something like the measles. It takes, it runs a course fairly well defined, you get over it, you forget it, but you can have it twice.

I have no doubt that this is not the first smoke-abatement movement that St. Louis has enjoyed. I hope that this is the beginning of the last smoke-abatement movement, because one characteristic of a successful smoke-abatement movement is continuous, never-ending pressure. I cannot emphasize that too much. It has been the one thing which has been absent from

6/ City Manager Mag., vol. 8, June 1926, pp. 19-23.

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most of our smoke-abatement efforts. If the amount of intermittent, unsuccessful, misdirected smoke-abatement effort in the United States could have been concentrated and kept going, half a dozen cities would have been made spotless towns. What usually happens is that some good, earnest workers, perhaps because the weekly wash has been badly smudged, will get together and do something in smoke-abatement work. They will get people interested, and like all good Americans, the first effort is usually "Let's have a law," "Let's pass an ordinance," with the hope that that will cure the smoking. Those that get a little farther in this cycle, always want to buy a smoke consumer, that indefinite something which some think can be perched on top of the chimney, others think can be introduced through the fire door of the furnace, but at any rate it is something which, once bought and paid for, can be expected to do the work without attention. Now, that is all a mistake. It is not that kind of a problem. I want to impress on this audience the magnitude and character of the problem that you are starting on. Let us look at it historically for a minute. This matter has its roots clear back in history at a time when we tried to get warm in a cave probably, and some of our ancestors were killed with carbon monoxide trying to build a fire in a closed space.

As I have indicated, many cities have, for some hundreds of years, faced this problem.. No small effort, no temporary effort, no enthusiastic effort of the moment, is going to abate smoke. We have no illustrations of success anywhere as the result of that kind of an effort. In looking over the many cities that have made efforts of this sort I always have a feeling of regret that so much enthusiasm and good work has not been properly directed.

Municipal Housekeeping

Let us compare the job to some other municipal housekeeping jobs. What would you think of a growing city that had come to the conclusion that it was no longer healthy or proper to draw water from the running streams for drinking purposes without preparation or treatment, and that made an effort to get clean, pure drinking water, and the enthusiastic effort of this year they failed to support next year, forgot it the third year and went back to drinking stream water the fourth year. That would not be a progressive American method of handling the problem of clean water for drinking, but we follow some such program in the cycle of smoke-abatement effort.

What would you think of a community that was raising itself up out of the mud of our western prairies, which would build a block or two or three of good pavements; would then discharge its engineers; would fail to keep the streets clean? You do not get good streets that way. You must have a continuing organization, planning and looking ahead for some years. Take the same thing with your efforts to maintain a clean moral atmosphere. What do you do? Do you hire a police force for a month, a year, or two year and then discharge them? No, you do not do it that way. How is it with taking care of municipal wastes - your sewer system - that is needed to keep

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a municipality clean? You have an organized body of engineers looking into the future, planning work, and you maintain it all the time and expect good results, and yet let me say that in almost every community I have gone into and looked into this smoke-abatement business, I find people do not think of it in that way. They think of it in the same way as they do a local difficulty - something to get out and hurry up and fix up this year, and then forget it next year. Now, I hope I have made my point, that if you are to do anything with smoke abatement, it is not a 1 year or 2 years or 5 years campaign. It is a continuous addition to your city budget, comparable with your other major housekeeping projects. It calls for a continuous effort on the part of your people and you must convince the people as a whole, that they really want it. We have had a wonderful change of opinion of late years as to what constitutes good roads. We need the same sort of change of opinion as to what constitutes an effective smoke abatement movement.

This problem is a combination problem. It is technical on the one hand and intensely human on the other. On the technical side the situation is practically settled. I can say this, I think there is no operation, no service being performed by bituminous coal in the city of St. Louis under conditions which are giving you smoke in your atmosphere, but what can be found somewhere, quite possibly in your own city, being carried on successfully, economically and smokelessly. In other words, it can be done.

As far as the technical phase of it goes, the solution of the problem can be found. The more difficult part of the problem is the human problem. One of the strange things about this problem is that we are rarely troubled with our own smoke. It is our neighbor's smoke that troubles us. We are all quite willing to have our neighbor regulated. The difficulty comes, in this human problem, of being willing to be regulated ourselves. In any smoke abatement movement there always has been, and always will be, opposition. There are people who insist that it will injure business, and, of course, we are a very "business" nation. Without arguing about it, let us see what the net result is in places where some success has been achieved. The net result has been, in almost every case, that the objectors have finally been converted; that they find when they face the real problem with a "I must do it" that the result is satisfactory. It has not cost so much as they have feared, and the cost is entirely made up by better performance. It is the problem, therefore, of the smoke-abatement organization, whatever form it may have, to get that idea across to the business man. He must first get over his nervousness, over the feeling that this little item affecting about 2 percent of his yearly costs is going to be so seriously attacked that it is going to be a serious thing in his business. In round numbers, the cost of production of power for manufacturing and work of that sort is, I am told, about a 2-percent item, and that is one reason why so little attention is given it.

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Elements of Successful Program

What are the elements of a successful smoke-abatement program? In picking out these elements, as I told you, I have a composite of the efforts that have been made in almost every city in the country. The first requisite is aroused public opinion and support. Without that it is practically useless for any small minority, any small body of people, to hope to get anywhere with the problem. The idea can be sold to a community by using all sorts of organizations. The women's clubs, church organizations, the Boy Scouts, the Girl Scouts, the business associations and organizations of all kinds, can get behind such a movement and produce a real effect in a community. It has been done.

Another necessary element is vision. This must be caught from those gifted people who are so situated that they can look beyond tomorrow and look at next year, the next decade, and what your beautiful city is to be 20 years hence. Instead of pounding away at the immediate effect one must look ahead, as I said before, 20 years. If you want this city to be any better than it is now 20 years hence, to begin tomorrow morning is none too early. Smoke abatement is a matter that does not cure itself in any case, except in decadence and death of a community. How are you going to bring to bear that kind of influence on a problem of this sort? Frankly you do not find it in the large body of people. You must find it in those relatively few people who are willing in this country to devote themselves unselfishly to the future of our American cities. That means some sort of a selected committee to act as godfather, or more likely godmother, to a problem of this kind - some sort of a commission, neither paid nor having political connections. It must be taken out of politics. Time and again have I seen efforts killed by too close connection with the political machine. It always furnishes a few jobs, and it looks as though these jobs were easily had, and when that time comes that spells death to an effective movement.

I have mentioned one other factor and tried to drive it home, and that is continuous effort. I am sorry to say that the best illustration I have in America today of successful work in smoke abatement has just had a setback because of a new political element who could not quite see the use of sufficient personnel to continue some necessary phases of that work. The situation is temporary, and I know it will be fixed, but it is one of the discouragements that must be met in this work.

Another necessary element is technical ability. I am going to tell you a little later of some of the things that the smoke-abatement organization must do. It cannot sit in an office, write letters, dictate, and get results. It must go into the several boiler rooms; it must look into technical details; it must get its hands and its face dirty; it must know the individuals; it must know the black man who is handling the shovel; it must be able to tell him when he is doing something wrong. When the inspector calls at the office to enter a complaint as to the management of the plant, he must give sound technical advice of a constructive nature.

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Mere complaint is not sufficient. He must be able to tell that man what he should do. He must be able to give good advice, reasonably practical under the conditions or the effort will die.

I think I have shown enough to indicate the next element of success. It takes a tremendous amount of tact and good judgment on the part of the individual who heads this movement, and to steer an effort which is always in trouble, for it deals with trouble. You must get some one who has a rather unusual combination of abilities and when you have that and it is successful, it must be supported or it will be taken away from you. It is rare, let me say. Already this year (and the year is but 1 month old) I have been asked for three men to head up movements of this kind. They are very scarce. They are difficult to find, and good ones are worth good salaries. One other element of success, and it is the most important of all. That is the cooperation of the offenders themselves. The wielding of the big stick; the attempt to pull the law on somebody will not abate smoke. It must be done by a combination of these elements of tact, good sensible advice and demonstration that it can be done. All of this has been done in successful efforts. The Bureau of Mines has observed these efforts, and recommends a certain general plan. I am not familiar with your local situation. It may be that many of these steps have already been taken, but at any rate in those places where we have seen successful efforts, something along the following line has been the plan.

First, there is the commission that I mentioned, of farseeing spirits in your community that act from unselfish motives, that father, or mother, the project. This commission should be of your most substantial and most influential citizens; people whose word is accepted in the community; people who are not simply busy uplifters, but good substantial people. Then there should be a board of engineers to act as referees in case of doubt when some individual feels that the smoke-abatement man has been particularly hard on his plant and he just don't want to come across, and rather doubts the soundness of the advice that has been given to him. There should then be available the advice of a board of engineers that are not paid, that, like your commission, serve because of their love for the community and their desire to give service, and that board should stand back of these particular cases as they are brought up. Then, of course, there must be the working organization depending upon the size of the community, a chief smoke inspector with the ability and tact mentioned, and the other inspectors that are needed.

The best way of making a beginning that we know of is what is called a "smoke survey." Here is something that happens over and over again. An excellent effort is made, a good man is obtained, the matter is carried on with tact, it goes on for 2 or 3 years, some real results are obtained, but there comes a bad year. Something happens. There are a few foggy days grouped together. There is a period of annoying smoke specially noticeable. The word goes out that things are not one bit better than they were some years ago. When this happens, how are you going

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to prove that you are any better than you were 4 years ago? So long as the matter rests on opinion, there will come a time when all your efforts will be discredited. The only safeguard that I know of, to a successful, continual smoke abatement movement, is to be able to reduce the thing to a system of bookkeeping - something that can be expressed in figures, in exactly the same way your bank account is expressed. It must come out in figures that can be brought into court in order to show whether you are going back or forward, whether this particular industry is getting ahead or going backward in its smoke abatement efforts. Such a survey gives figures which act as an insurance, paid for at the beginning of your efforts, to insure continued life. Here is another thing that happens over and over. The sawmill, the laundry, and foundry are very sure that their industries furnish only a small amount of smoke, that most of the smoke comes from the railroads, and everybody knows it. The railroads are quite sure that it is not the railroads. I was told today in this community that, as a matter of fact, the industries in the center of the town did not supply much of the smoke; that the trouble here was with the domestic smoke.

When your smoke-abatement man begins his work, where should he begin? Is it industrial smoke that is troubling you? Is it railroad smoke? Is it domestic smoke? Is it smoke from the smelters, or some other industry? Just so long as you are unable to express in figures the facts of the case you will have this merry-go-round of each blaming the other fellow for being the worst offender, and getting nowhere. The "smoke survey" would allocate the responsibility for the amount of smoke coming from each smoking chimney in the city of St. Louis. Figures can be obtained which will tell John Smith's laundry just the proportion of smoke he is bringing into the town. When you have figures of that sort, and there comes criticism, you will have the facts, and on the basis of facts you can build an edifice for the future. Without such facts the chances are the movement will stop.

Now, there comes the question, "What is smoke?" We have in the city of Washington a smoke-abatement law. Our Congress has given an edict that in the city of Washington there should be "no smoke." Those who have been there lately will have noticed that the mere passing of the law has not eliminated smoke. This year, for instance, it is darker than it has ever been. The law leaves it for the administrator to define what smoke is, and that particular administrator in the Health Department has said that if a chimney does not smoke over 15 seconds he cannot see it. Now, that is not in the law, but that is his interpretation of it. He has difficulty administering a law of that sort. One method of defining smoke is to determine how much light is cut off by the cloud of smoke. If, for instance, 20 percent of the light is cut off, then it is called No. 1 smoke. If 40 percent of the light is cut off it is called No. 2 smoke. If it is a jet black (and I saw last year in Pittsburgh for 10 minutes at 10 o'clock in the morning, absolute jet-black darkness) that would be called No. 5 smoke. Smoke can therefore be defined as to density. There is also a considerable difference in quality of smoke. Smoke from your large power plants, high-pressure boilers, furnaces that are pushed, is quite different in

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character when you look at it with a microscope and analyze it chemically from the smoke that comes from domestic heaters and stoves. The latter kind of smoke is much worse on your curtains, on the membranes of your throat, and is a good deal harder to deal with since it carries with it the makings of sulphuric acid. So there is a difference in the kind of smoke as well as the density.

You will find that power plant soot carries relatively large amounts of ash. You will find that soot from locomotives is made up pretty largely of coke. You will find that what comes from the stack of your Cahokia plant, where they use powdered coal, as seen under a microscope, shows some pretty coke balloons with little transparent windows which are very interesting. Along with the soot, there are certain gases, and these gases may be deleterious to vegetation, and the soot and the tar predispose to bronchial and nasal troubles.

The coal that is available to this community is a high-volatile coal. It is a pretty good coal. I know coals that are a whole lot worse than the coals that are tributary to St. Louis. As a matter of fact, Pittsburgh coal is harder to burn smokelessly than your Illinois coal. When coal is heated tar and oils and things of that sort are distilled from it. These particular things are rather difficult to burn, and therefore your method of burning must be right. If you were supplied with tar to burn, you would have difficulty in burning it on a grate, but there are ways of burning tar that will give smokeless combustion. The burning of coal, as you all know, is a combination of air or oxygen with the carbon and gases of the coal, and that combination is made only when there is sufficient temperature and when the gases are brought into immediate contact. This is no place to talk deeply on the technics of burning, but there are certain remarks that may help.

For good combustion you must have time, temperature, turbulence, and uniformity. We can group our own ideas of combustion about those four words. There must be time to complete the process of combustion before gases are chilled too much and carried out in the atmosphere. That must all take place in the combustion chamber of your furnace, and if that is too small, if there is too short a path from the time it is ignited until it goes up in the tubes, the combustion will not be complete, and smoke will result. The conventional size of our furnaces has been determined pretty largely by practice with eastern coals. It was determined pretty largely by practice with anthracite, which is a very different proposition, and the whole tendency in engineering in late years has been toward larger combustion space, in order to give this element of time to complete combustion. Return tubular boilers, which are very commonly set low (I have seen them as low as 24 inches above the grate) have too small combustion space for smokeless combustion. There must also be a certain minimum temperature or these chemical combinations will not take place. That is why we put firebrick around the furnace. We put in refractory arches to reflect the heat, and we make an effort to keep up the temperature until these gases have been burned.

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The element of turbulence has been most difficult to obtain. These three facts each help the other. You can sacrifice on one if you increase the others. You can have a little less turbulence if you give more time and temperature. It is a very common experience to find more air than is needed, and yet there is incomplete combustion. That simply means the gases do not have a chance to get together. Steam or air jets are used to produce turbulence where better means are not available. A great many of the devices that are sold and patented, furnaces with wing walls, are simply for the purpose of mixing gases so that they can make the proper combination. Many of the ideals of good combustion cluster around the word "uniformity." There should be a uniform fire bed, uniform supply of coal of uniform size, and with this a uniform supply of air. We violate these in most of our work in firing coal. Do you put coal in the fire in a perfectly uniform stream? No. We put in a dozen or twenty shovelfuls and then we sit down and smoke for twenty minutes. We are janitor, or something else, and come back periodically to do this job of firing. That is far from feeding coal uniformly, and that is one reason we have smoke. Mechanical methods of feeding coal uniformly are a great improvement, and make smokeless combustion possible.

There are many firing methods that are bad, and there are a few that are good. A really skillful fireman is rather hard to find, and when he is found he ought to be paid what he is worth. The general level of opinion about firing coal is that it is a very simple matter and should be a poorly paid job. That is wrong. You are not going to get smoke abatement with people of that sort. When you make good firing worth while by recognizing skill, paying for it and making it worth while, you will get it. You won't get it until you do. There are a great many patented furnaces and smokeless devices. You had better call in your mechanical engineer and get some advice before going too far in investment of these. Very often the complicated ones are not worth looking at. A furnace is a relatively simple thing, but it must be right. Many foolish cure-alls are presented to the public to cure the smoke evil. I can buy here in St. Louis a fuel-saving powder. You dissolve 8 ounces of this in 12 quarts of water and sprinkle it on 1 ton of coal and 1 ton of coal will go as far as 2. It does not say where, what or how. You would be surprised to find such fuel-saving powders are all over the world. England, France, even scientific Germany falls for them. They are made of common salt, potash salts, and some sort of coloring matter. They are entirely ineffective. We have also devices that can be put on the fireboor. They are peddled from house to house, to introduce air over the fuel bed, and I am sorry to say that they refer to our Bureau of Mines bulletins in order to prove their case, and these, too, are rarely worth looking at. They are not needed. They do not function as proposed.

I am going to give you just one illustration of a smoke-abatement report. Some years ago the City of Salt Lake became anxious about its tourists' trade. People no longer stopped at Salt Lake City. They said the town was too smoky. A survey of the kind I told you about was made, and the responsibility allocated for the smoke made. The people who had

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brought to us the complaint, and who put up the money pretty largely for the survey, were found to be principal offenders. This survey resulted in a smoke ordinance, in the establishment of an organization, and this is their fifth report that I quote from.

> The total amount of smoke produced by the heating and industrial plants in Salt Lake, exclusive of private residences in 1925, was 66 percent of the amount produced in 1924, 42 percent of the amount produced in 1923, 27 percent of that produced in 1922 and 4 percent of that produced in 1919, which is a reduction of 96 percent since the smoke abatement work started in 1920.

That is the basis for my statement that it can be done.

The Weather Bureau records show that during the 5-year period of smoke-abatement work, the number of hours of light smoke, that is, smoke which obscures the distant view, has been reduced 22 percent, also that the number of hours of dense smoke, that is, smoke which obscuredthe view at and behind 1,000 feet, has been reduced 57 percent in this period. Our smoke-abatement campaign during the winter months was carried on on exactly the same plan as that employed in the last few years - that is, careful instruction of firemen in the proper methods of handling plants under their control, urgent inspection of plants to see that they are maintained in proper condition, and the constant inspection of plants by our inspectors. These inspectors have the instruction of firemen, and as a secondary duty they caution the fireman when he slips up, give him any assistance that may be necessary, when smoke occurs from breakdowns or other causes. Every plant possible is notified within 1 minute of the time their smoke starts that their plant is producing objectionable smoke. It is a follow-up system. The total number of inspections made by this department, including industrial plants and private homes, was 6,672. Police and court prosecutions were not attempted in any case during the year. There were perhaps some cases where it would have been wisdom to resort to prosecutions. The number of violations recorded during the period from October 15 to December 31, 1925, was 329. For the same period the previous year it was 643, a reduction of 49 percent.

His report of what was done during the year follows:

Permits issued for boiler and heating plants	962
Certificates of approval issued	854
Inspections of heating and industrial plants	4068
Inspections of new resident heating plants	2308
Locomotive firemen reported for smoke ordinance violations	288
Power plants investigated in detail	8
Plants for large changes recommended	83
Calls to persuade the owner to comply with recommendations	151
Plants remodeled	34
Cases prosecuted in the police court	None

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THE HOOD PLAN

The six essentials of a successful smoke-abatement program, presented by Mr. O. P. Hood, chief mechanical engineer of the Bureau of Mines, of Washington, D. C., summed up under the general heading of "The Hood Plan," as follows:

1. An aroused public opinion which will support a safe and sane smoke-abatement program.

2. A vision on the part of people who are gifted in the direction of such movement, and who will take it in charge, not only for a month or a year, but will give it that continuous and systematic effort over a long period which is necessary for the success of any enterprise.

3. Technical ability. There must be that expert engineering service which will properly direct the installation and operation of all furnaces - household, heating plants and power plants, which are liable to make smoke. This engineering service should be in seven distinct classes, i. e.:

   (a) Our Municipal Smoke-Abatement Administration should have the power and should employ the necessary engineering talent to direct and pass on the construction of furnaces and chimneys so that they will be most suitable for smokeless combustion. The Director of Public Safety should also employ such engineering talent as may best direct the operation of all such equipment, and should have power to insist on the cooperation of plant owners, engineers, householders, and all who have charge of the operation of furnaces, with his engineers in securing smoke abatement.

   (b) The various engineering organizations should contribute of their technical ability in solving the various phases of this problem.

   (c) The coal operators should be sufficiently interested in the use of coal, from which a large part of the smoke comes, to employ engineering talent to assist the Director of Public Safety and the Smoke Commissioner, in directing the proper selection and use of their product.

   (d) The coal retailers or distributors should be sufficiently interested in the proper selection and use of coal by their customers to employ proper engineering and demonstrating talent to assist the Director of Public Safety and the Smoke Commissioner in educating their salesmen and the people in the proper and smokeless operation of their stoves and furnaces.

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(e) The large consumers of coal should be sufficiently interested in saving coal and preventing smoke to employ proper engineering talent to direct the operation of their furnaces in an efficient and smokeless manner. It has been shown that in most cases a handsome net saving will result to the user of coal after paying for this engineering service and furnace equipment.

(f) The householder, who produces a very large proportion of the smoke in our city, should be sufficiently interested to cooperate with the engineering and demonstrating service furnished by the Director of Public Safety, the coal industry and the Woman's Smoke-Abatement League in preventing smoke and saving coal.

(g) The manufacturers of household and apartment furnaces, of other heating plant equipment, and of factory and power plant equipment should be sufficiently interested in building and merchandising a high grade product, designed for the efficient and smokeless combustion of fuel, to employ the proper engineering talent for the designing and installation of this equipment. They should not be subjected to the necessity of selling and installing the cheapest equipment that can possibly be produced in order to get a sale for their product. The Director of Public Safety, backed by an aroused public opinion, should demand high grade chimney and furnace equipment, without regard to its cost.

4. The survey. There should be a "Smoke Survey," which will result in definite information as to who produces the smoke, when, and what proportion it bears to the total.

5. The City Smoke Department in charge of the Director of Public Safety. The whole movement must be headed up under the direction of the Director of Public Safety and the Smoke Commissioner. We are very fortunate in having a man in charge of this department who can ably head up the whole movement.

6. Cooperation. 'In order to have large and continued success, there must be cooperation of all the forces and agencies interested in or affected by the smoke problem. The women's organizations and the Chamber of Commerce must be largely responsible for the development of the necessary public opinion. The engineers must furnish the technical ability. The business men must lay out a program with a vision of the work for years to come. The furnace manufacturers, the coal industry, the women's organizations and the engineers must cooperate with the Director of Public Safety in carrying through a program which will be for the benefit of all classes, and have the support of all classes.

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